PHYSICS

PAPER 2 TOPICS

REVISION ORGANISER

Chapter 8: Forces in balance

Knowledge organiser

Scalars and vectors

Scalar quantities only have a magnitude (e.g., distance and speed).

Vector quantities have a magnitude *and* a direction (e.g., velocity and displacement).

Forces

A **force** can be a push or pull on an object caused by an interaction with another object. Forces are vector quantities.

Contact forces occur when two objects are touching each other.
For example, friction, air-resistance, tension, and normal contact force.

Non-contact forces act at a distance (without the two objects touching).
For example, gravitational force, electrostatic force, and magnetic force.

Newton's Third Law

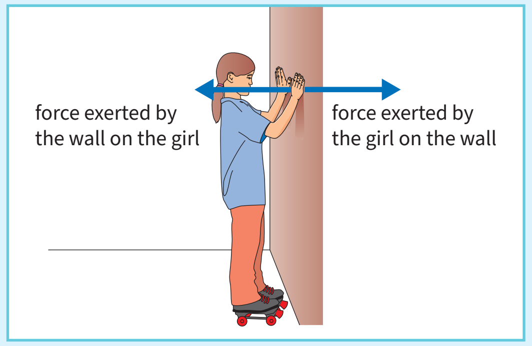
Newton's Third Law states that whenever two objects interact with each other, they exert *equal and opposite* forces on each other.

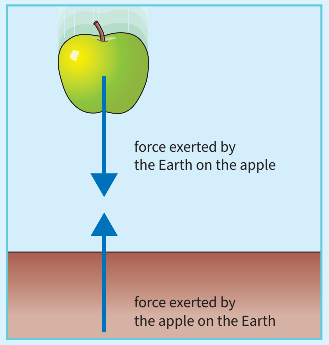
This means that forces always occur in pairs.

Each pair of forces:

- act on separate objects
- are the same size as each other
- act in opposite directions along the same line
- are of the same type, for example, two gravitational forces or two electrostatic forces.

Force pairs





Resultant forces

If two or more forces act on an object along the same line, their effect is the same as if they were replaced with a single **resultant force**. The resultant force is

- the sum of the magnitudes of the forces if they act in the same direction
- the difference between the magnitudes of the forces if they act in opposite directions.

If the resultant force on an object is zero, the forces are said to be **balanced**.

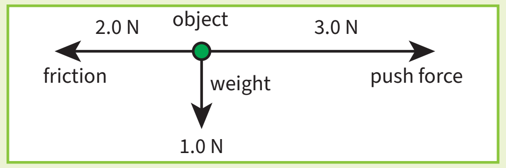
Newton's First law

Newton's First Law states that the velocity, speed, and/or direction of an object will only change if a resultant force is acting on it. This means that:

- if the resultant force on a stationary object is zero, the object will remain stationary
- if the resultant force on a moving object is zero, it will continue moving at the same velocity, in a straight line.

Drawing forces

Free body diagrams use arrows to show all of the forces acting on a single object. For example:



A dot or circle represents the object, with the forces drawn as arrows:

- the arrow length represents the magnitude of the force
- the arrow direction shows the direction of the force.

Key terms

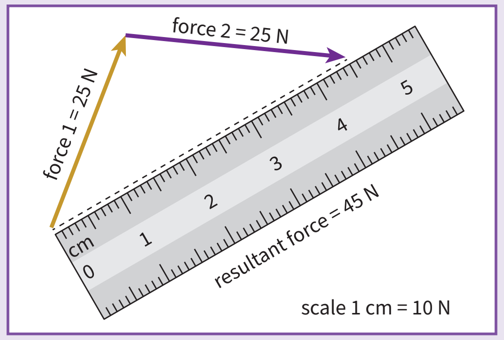
Make sure you can write a definition for these key terms.

balanced · centre of mass · contact force · free body diagram · force pair · force · gear
lever · moment · Newton's First Law · non-contact force · resultant · scalar · vector

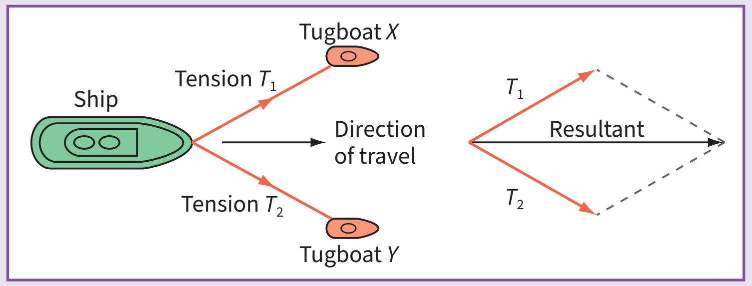
Scale drawings (HT only)

Scale drawings can be used to find the resultant of two forces which are not acting along the same line.

The forces are drawn end to end. The resultant can then be drawn between the two ends, forming a triangle.

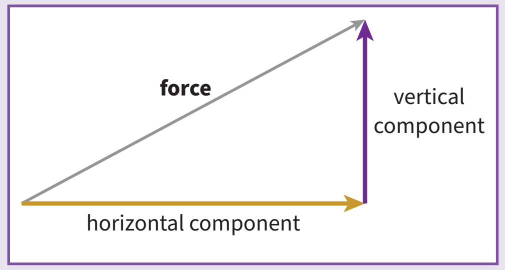


You can use the parallelogram of forces where the two forces are drawn to scale as sides of a parallelogram.



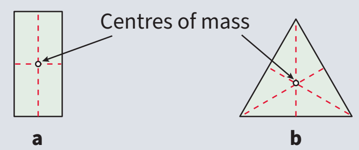
Resolving forces

A single force can always be resolved (split) into two component forces at right angles to each other:



The two component forces added together give the same effect as the single force.

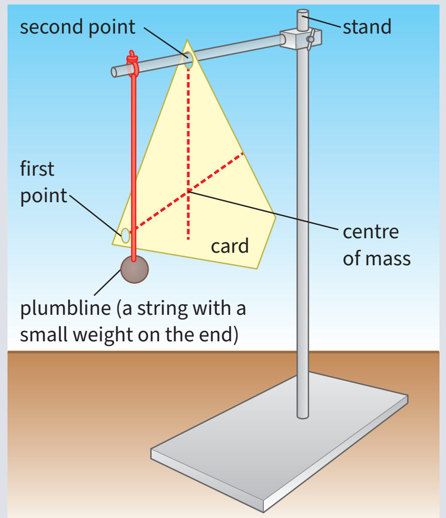
Centre of mass



For a flat symmetrical object, the centre of mass is where the axes of symmetry meet.

The point through which the weight of an object can be considered to act.

For a flat irregularly shaped object, find the centre of mass by suspending the object from different points. The centre of mass always lies beneath the point of suspension.



Moments

A force or system of forces can cause an object to rotate.

The turning effect of a force is called the **moment** of the force, and its size can be calculated using the equation:

moment of a force (Nm) = force (N) × distance (m)

$$M = F\,d$$

If an object is balanced, the sum of the clockwise moments equals the sum of the anticlockwise moments.

Levers and gears

Levers and **gears** can be used to increase the moment of a force, making it easier to lift or rotate an object.

If a small gear drives a large gear, the moment of the applied force is *increased* but the large gear moves slower (and vice versa).

A lever allows a large moment of force to be produced by allowing force to be applied further from the pivot.

Chapter 9: Motion

Knowledge organiser

Speed

distance travelled (m) = speed (m/s) × time (s)

$$s = v \times t$$

The symbol for distance is s, and the symbol for speed is v.

In reality, objects rarely move at a constant speed. So it can be useful to calculate average speed:

$$\text{average speed (m/s)} = \frac{\text{total distance travelled (m)}}{\text{total time taken (s)}}$$

Some typical average speeds are:

- walking ≈ 1.5 m/s
- running ≈ 3 m/s
- cycling ≈ 6 m/s

The speed of sound and the speed of the wind also change depending on the conditions. A typical value for the speed of sound is 300 m/s

Velocity

The **velocity** of an object is its speed in a given direction.

Velocity is a vector quantity because it has a magnitude and direction.

An object's velocity changes if its direction changes, even if its speed is constant.

An object moving in a circle can have a constant speed but its velocity is always changing because its direction is always changing.

Acceleration

Acceleration is the change in velocity of an object per second. It is a vector quantity.

The unit of acceleration is metres per second squared, m/s^2.

An object is accelerating if its speed or its direction (or both) are changing. A negative acceleration means an object is slowing down, and is called **deceleration**.

Acceleration can be calculated using:

$$\text{acceleration (m/s}^2\text{)} = \frac{\text{change in velocity (m/s)}}{\text{time taken (s)}}$$

$$a = \frac{\Delta v}{t}$$

Uniform acceleration is when the acceleration of an object is constant.

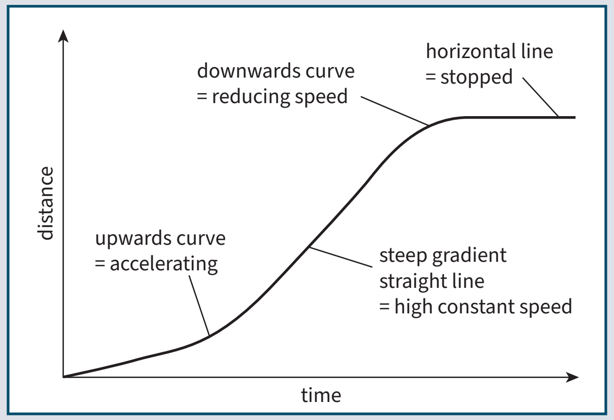
The following equation applies to objects with uniform acceleration:

(final velocity)^2 – (initial velocity)^2 = 2 × acceleration × distance

$$v^2 - u^2 = 2as$$

Distance–time graphs

A distance–time graph shows how the distance travelled by an object travelling in a straight line changes with time.

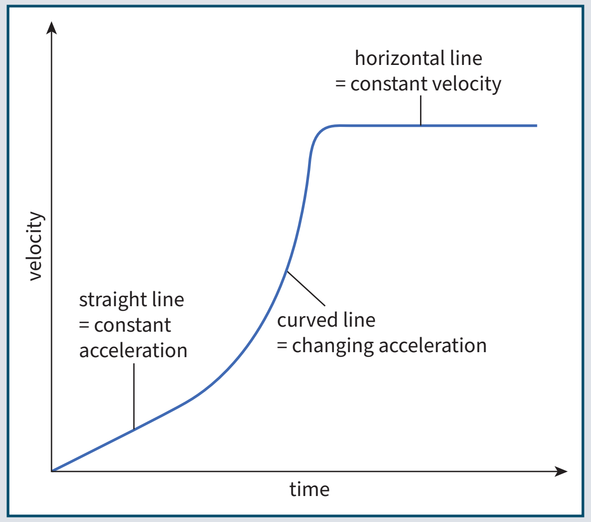


The gradient of the line in a distance–time graph is equal to the object's speed.

If the object is accelerating, the speed at any time can be found by calculating the gradient of a tangent to the curved line at that time.

Velocity–time graphs

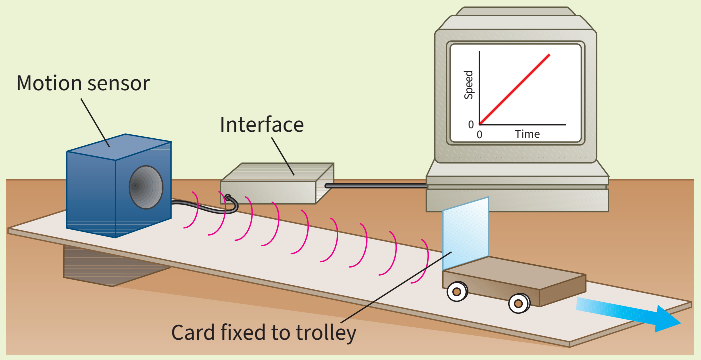
A velocity–time graph shows how the velocity of an object changes with time.



The gradient of the line in a velocity–time graph is equal to the object's acceleration.

Investigating acceleration

Motion sensors which are attached to a computer can be used to record how the velocity of an object changes.

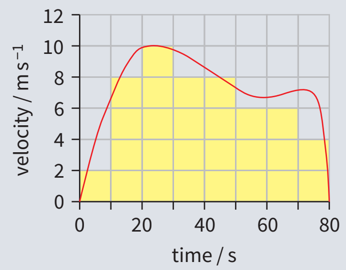


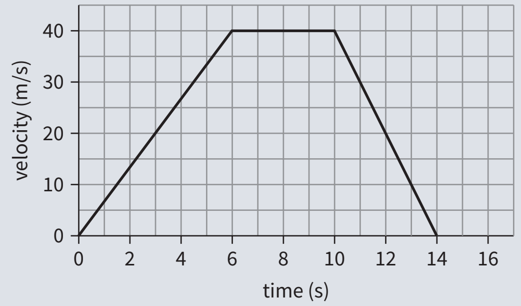
As the trolley accelerates down the runway, the velocity increases with time. Therefore, the line on the graph will go up and remain straight to suggest that the acceleration of the trolley is constant.

Alternatively, making the runway steeper will mean the trolley accelerates faster, and the line on the graph will be steeper.

Displacement (HT only)

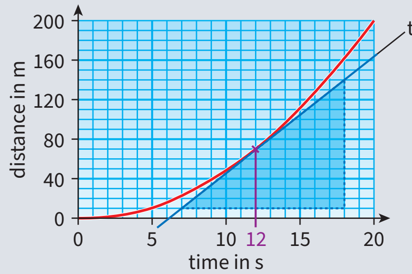
The displacement of an object, or the distanced travelled by an object, can be calculated from the area under a velocity-time graph. This can be done by measuring or counting squares.

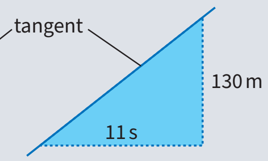




Finding the gradient of a tangent (HT only)

A **tangent** is a straight line which touches the curve at a point and is drawn in the direction of the slope at that point.





at time = 12 s,

gradient of triangle = $\frac{\text{height}}{\text{base}}$

speed = gradient of triangle = $\frac{130\text{ m}}{11\text{ s}}$ = 11.8 m/s

The speed at 12 seconds is 118 m/s

Key terms

Make sure you can write a definition for these key terms.

acceleration *deceleration* *displacement* *gradient* *speed* *tangent* *uniform acceleration* *velocity*

Chapter 10: Force and motion 1

Knowledge organiser

Force and acceleration

If the velocity of an object changes it must be acted on by a **resultant force**. The acceleration is always in the same direction as the resultant force.

Gravity

The force of **gravity** close to the Earth is due to the planet's **gravitational field strength**.

Weight is the force acting on an object due to gravity.

The weight of an object

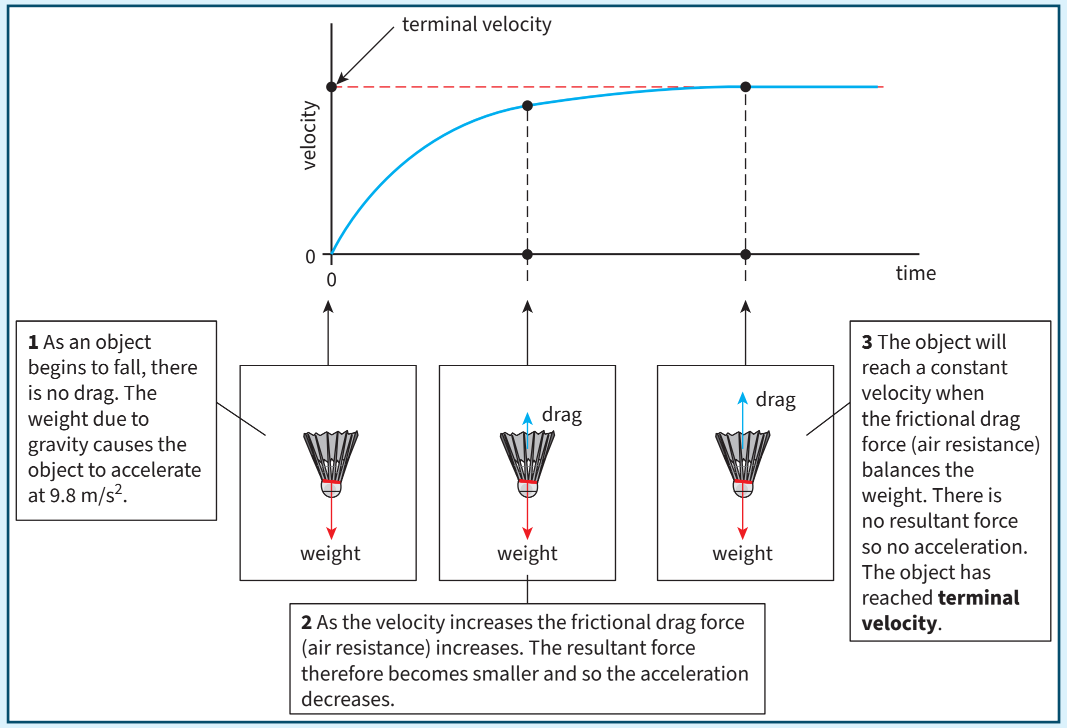
- can be considered to act at the object's **centre of mass**
- can be measured using a calibrated spring-balance (newtonmeter).

weight (N) = mass (kg) × gravitational field strength (N/kg)

$$W = m\,g$$

Weight and mass are directly proportional to each other, which can be written as $W \propto m$, so as the mass of an object doubles, its weight doubles.

Graph of terminal velocity



Newton's Second Law

Newton's Second Law says that the acceleration a of an object:

- is proportional to the resultant force on the object

$$a \propto F$$

- is inversely proportional to the mass of the object

$$a \propto \frac{1}{m}$$

Resultant force, mass and acceleration are linked by the equation:

resultant force (N) = mass (kg) × acceleration (m/s^2)

$$F = ma$$

The **inertial mass** of an object is a measure of how difficult it is to change the velocity of an object. It can be found using:

$$\text{inertial mass (kg)} = \frac{\text{force (N)}}{\text{acceleration (m/s}^2\text{)}}$$

$$m = \frac{F}{a}$$

Terminal velocity

For an object falling through a fluid:

- there are two forces acting – its weight due to gravity and the drag force
- the weight remains constant
- the drag force is small at the beginning, but gets bigger as it speeds up
- the resultant force will get smaller as the drag force increases
- the acceleration will decrease as it falls
- if it falls for a long enough time, the object will reach a final steady speed.

Terminal velocity is the constant velocity a falling object reaches when the frictional force acting on it is equal to its weight.

If an object is only acted on by gravity the acceleration will be 9.8 m/s^2

Momentum (HT only)

Momentum is a property of all moving objects. It is a vector quantity.

Momentum depends on the mass and velocity of an object and is defined by the equation:

momentum (kg m/s) = mass (kg) × velocity (m/s)

$$p = mv$$

Law of Conversion Momentum (HT only)

The **Law of Conservation of Momentum** says that:

In a closed system, the total momentum before an event (a collision or an explosion) is *equal* to the total momentum after the event.

If two moving objects collide the law of conservation can be written as:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

m_1 = mass of object 1 m_2 = mass of object 2

u_1 = initial velocity of object 1 u_2 = initial velocity of object 2

v_1 = final velocity of object 1 v_2 = final velocity of object 2

Momentum is conserved in explosions because:

- the total momentum before is zero
- the total momentum after is also zero because the different parts of the object travel in different directions and so the momentum of each part will cancel out with the momentum of another part.

If two moving objects **recoil** from each other, they start off with a total momentum of zero and end up moving away from each other with velocities v_1 and v_2. In this case, the law of conservation can be written as:

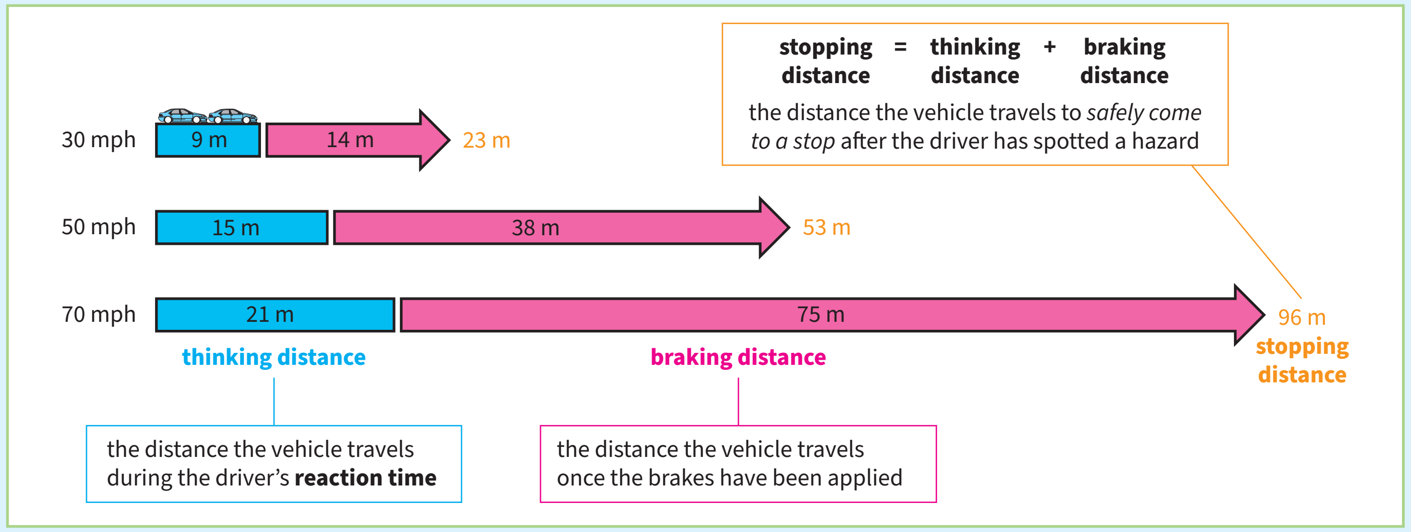
$$m_1v_1 + m_2v_2 = 0$$

Key terms

Make sure you can write a definition for these key terms.

acceleration centre of mass gravitational field strength inertia inertial mass law of conservation of momentum momentum Newton's Second Law recoil resultant force terminal velocity weight

Forces and braking



Factors affecting braking distance:

- speed of the car
- road conditions
- conditions of the brakes and the tyres

Factors affecting thinking distance:

- speed of the car
- tiredness
- drugs
- alcohol
- distractions

Deceleration (HT only)

Deceleration of a vehicle can be calculated using the equation

$v^2 = u^2 + 2as$

where *s* is the distance travelled, *u* is the initial speed, and *v* is the final speed.

Deformation

Deformation is a change in the shape of an object caused by stretching, squashing (compressing), bending, or twisting.

More than one force has to act on a stationary object to deform it, otherwise the force would make it move.

Elastic deformation – the object can go back to its original shape and size when the forces are removed.

Inelastic deformation – the object does not go back to its original shape or size when the forces are removed.

Changes in momentum

If an object is moving or is able to move, an unbalanced force acting on it will change its momentum.

Since $F = ma$ and $a = \frac{\Delta v}{t}$, we can write:

$$F = \frac{m\Delta v}{t}$$

where $m\Delta v$ is the change in momentum of an object.

The greater the time taken for the change in momentum of an object:

- the smaller the rate of change of momentum
- the smaller the force it experiences.

This means the force acting on an object is equal to the rate of change of momentum of the object.

Vehicle safety features increase the time taken for the change in momentum, e.g.:

- air bags, seat belts, and crumple zones in cars
- cycling helmets
- crash mats used for gymnastics

Impact forces (HT only)

The longer the impact time, the more the impact force is reduced.

When two vehicles collide, they exert equal and opposite impact forces on each other at the same time.

Therefore, the change of momentum of one vehicle is equal and opposite to the change of momentum to the other vehicle.

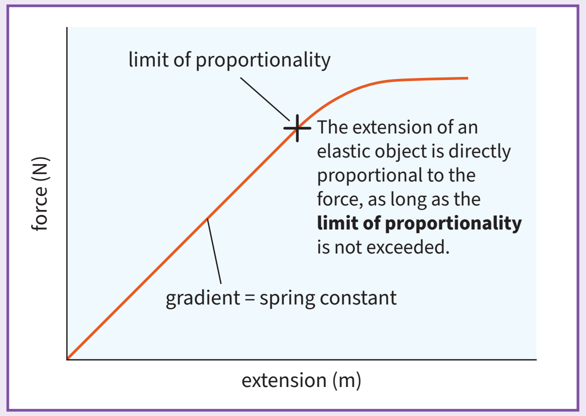
Graphs of force against extension for elastic objects

The spring constant can be calculated using the equation:

(L) force applied (N) = spring constant (N/m) × extension (m)

$$F = k\,e$$

This relationship also applies to compressing an object, where e would be compression instead of extension.



Key terms

Make sure you can write a definition for these key terms.

braking distance | deceleration | deformation | elastic | inelastic | limit of proportionality | reaction time | stopping distance | thinking distance

Pressure

Pressure is the force acting per square metre on a surface.

The unit of pressure is the **pascal** (Pa), which is equal to one newton per square metre.

Pressure can be calculated using:

(L) pressure (Pa) = $\frac{\text{force (N)}}{\text{area (m}^2\text{)}}$

$$p = \frac{F}{A}$$

When a force acts over a:

- large surface area, the pressure is reduced (e.g., caterpillar tracks on a tank)
- small surface area, the pressure is increased (e.g., knife edge).

Pressure in a substance

A **fluid** is a liquid or gaseous substance that can flow.

When the particles of a fluid collide with a surface, such as in a container, they exert a force at right angles (normal) to the surface.

Pressure at depth

The pressure in a liquid increases with the depth of the liquid because:

- the pressure at any point in a liquid is due to the weight of the liquid above that point
- the weight of a liquid depends on its **density**.

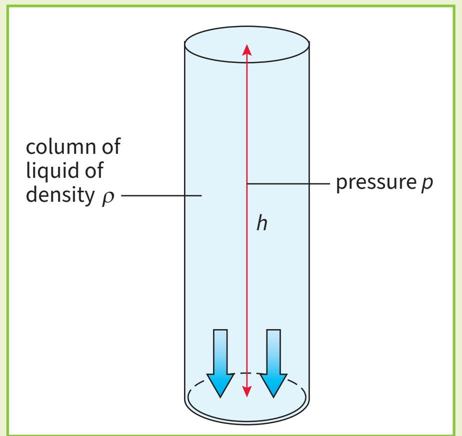
Calculating pressure in a column of water

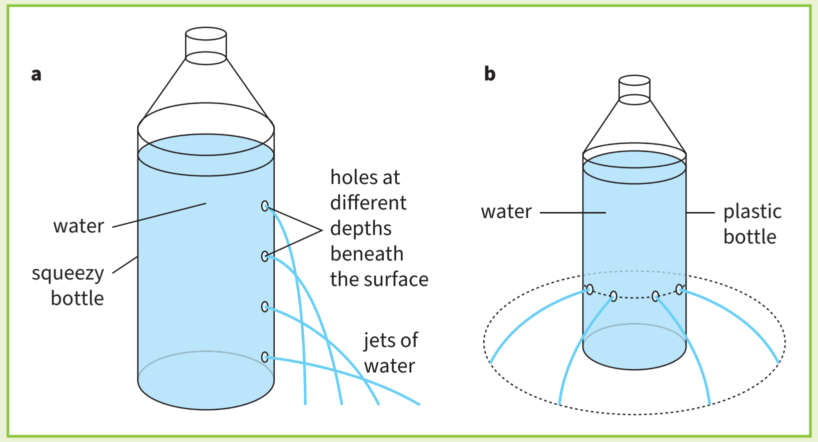
The pressure caused by a column of liquid can be calculated using:

pressure (Pa) = height of the column (m) × density of the liquid (kg/m^3) × gravitational field strength (N/kg)

$$p = h\,\rho\,g$$

To calculate the difference in pressure at different depths in a liquid, calculate the pressure at each depth (h) and subtract the smaller value from the larger one.

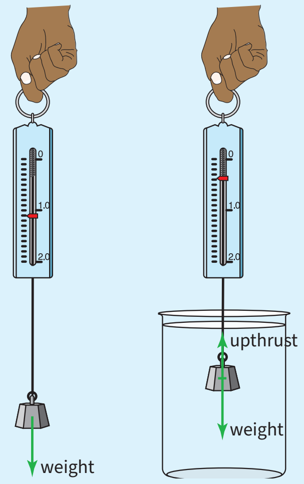




a) Pressure increases with depth b) Pressure is the same at the same depth

Measuring upthrust

Measure the weight of an object in air using a newtonmeter. Repeat with the object completely in water. The difference between the two readings is the upthrust.



Upthrust

An object that is partially or completely submerged in a fluid experiences a greater pressure on its bottom surface than its top surface.

This difference in pressure creates an upwards resultant force on the submerged object, known as **upthrust**.

Floating and sinking

An object will sink if its weight is greater than the upthrust.

An object will float if its weight is equal to the upthrust.

Whether an object in a fluid will float or sink depends on its density because:

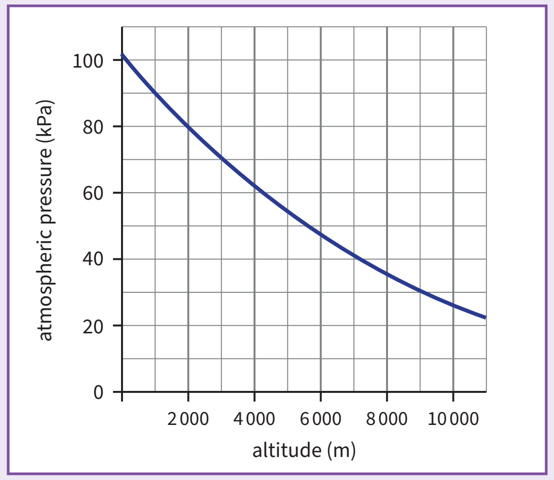
- the upthrust on an object is equal to the weight of the fluid it **displaces** (pushes out of the way)
- an object that is *more dense* than the fluid will sink because its weight is greater than the weight of the liquid displaced (and so greater than the upthrust)
- an object that is *less dense* than the fluid will float because its weight is less than the weight of the fluid displaced (and so less than the upthrust).

Atmospheric pressure

Atmospheric pressure is caused by air molecules colliding with surfaces. This decreases as height above a surface (**altitude**) increases because:

1. there are fewer air molecules in total above the surface as height increases, so the weight of air above the surface decreases
2. density of the atmosphere decreases with altitude, so there are fewer air molecules per cubic metre.

These both mean that atmospheric pressure decreases with increasing altitude because there is less **weight** of air above the surface.



The Earth's atmosphere

The Earth is surrounded by a thin (relative to the size of the Earth) layer of air known as the atmosphere.

Air is a fluid, so there is pressure in the atmosphere – this is called **atmospheric pressure**. As the altitude increases (e.g., walking to the top of a mountain), the concentration of oxygen in the atmosphere will decrease.

Key terms

Make sure you can write a definition for these key terms.

altitude   atmosphere   atmospheric pressure   density   displace   fluid   gravitational field strength   pascal   pressure   upthrust   weight

Chapter 12: Wave properties

Knowledge organiser

Waves in air, fluids, and solids

Waves transfer energy from one place to another without transferring matter. Waves may be **transverse** or **longitudinal**.

For waves in water and air, it is the wave and not the substance that moves.

- When a light object is dropped into still water, it produces ripples (waves) on the water which spread out, but neither the object nor the water moves with the ripples.
- When you speak, your voice box vibrates, making sound waves travel through the air. The air itself does not travel away from your throat, otherwise a vacuum would be created.

Mechanical waves require a substance (a medium) to travel through.

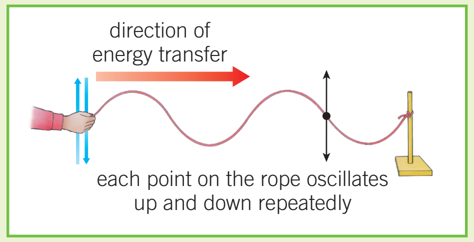
Examples of mechanical waves include sound waves, water waves, waves on springs and ropes, and seismic waves produced by earthquakes.

When waves travel through a substance, the particles in the substance **oscillate** (vibrate) and pass energy on to neighbouring particles.

Transverse waves

The oscillations of a transverse wave are *perpendicular* (at right angles) to the direction in which the waves transfer energy.

Ripples on the surface of water are an example of transverse waves.

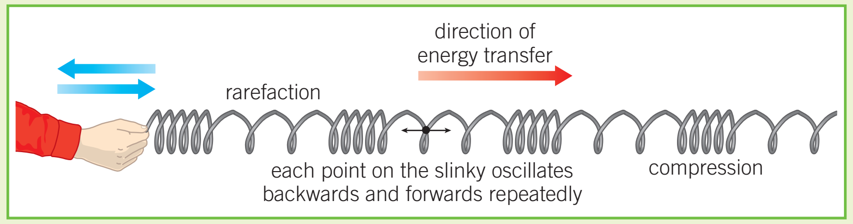


Longitudinal waves

The oscillations of a longitudinal wave are *parallel* to the direction in which the waves transfer energy.

Longitudinal waves cause particles in a substance to be squashed closer together and pulled further apart, producing areas of **compression** and **rarefaction** in the substance.

Sound waves in air are an example of longitudinal waves.



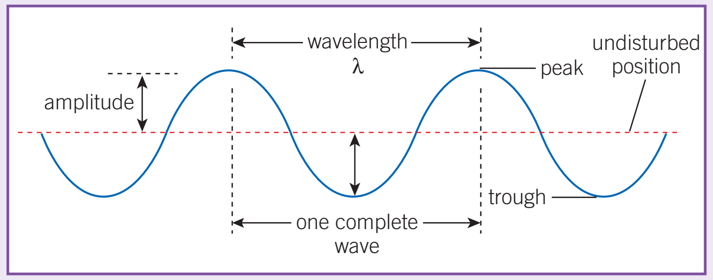
Wave motion is described by a number of properties.

Property	Description	Unit
amplitude A	maximum displacement of a point on a wave from its undisturbed position	metre (m)
frequency f	number of waves passing a fixed point per second	hertz (Hz)
period T	time taken for one complete wave to pass a fixed point	second (s)
wavelength λ	distance from one point on a wave to the equivalent point on the next wave	metre (m)
wave speed v	distance travelled by each wave per second, and the speed at which energy is transferred by the wave	metres per second (m/s)

Properties of waves

Frequency and period are related by the equation:

$$\text{period (s)} = \frac{1}{\text{frequency (Hz)}} \qquad T = \frac{1}{f}$$



All waves obey the wave equation:

$$\text{wave speed (m/s)} = \text{frequency (Hz)} \times \text{wavelength (m)}$$

$$v = f\lambda$$

When waves travel from one medium to another, their speed and wavelength may change but the frequency always stays the same.

The speed of ripples on water can be slow enough to measure using a stopwatch and ruler, and applying the equation:

$$\text{speed (m/s)} = \frac{\text{distance (m)}}{\text{time (s)}}$$

The speed of sound in air can be measured by using a stopwatch to measure the time taken for a sound to travel a known distance, and applying the same equation.

Reflection of waves

When waves arrive at the boundary between two different substances, one or more of the following things can happen:

Absorption – the energy of the waves is transferred to the energy stores of the substance they travel into (for example, when food is heated in a microwave)

Reflection – the waves bounce back

Refraction – the waves change speed and direction as they cross the boundary

Transmission – the waves carry on moving once they've crossed the boundary, but may be refracted

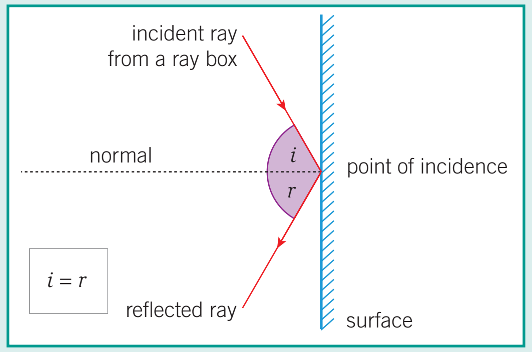
Ray diagrams can be used to show what happens when a wave is reflected at a surface.

To correctly draw a ray diagram for reflection:

1. use a ruler to draw all lines for the rays
2. draw a single arrow on the rays to show the direction the wave is travelling
3. draw a dotted line at right angles to the surface at the point of **incidence** (this line is normal to the surface)
4. label the normal, angle of incidence (i), and angle of reflection (r).

When reflection happens at a surface, the angle of incidence is always equal to the angle of reflection:

$$i = r$$



Key terms

Make sure you can write a definition for these key terms.

absorption amplitude compression frequency incidence longitudinal mechanical wave oscillate period ray diagram reflection rarefaction transmission transverse wavelength wave speed

Chapter 13: Electromagnetic waves

Knowledge organiser

The electromagnetic spectrum

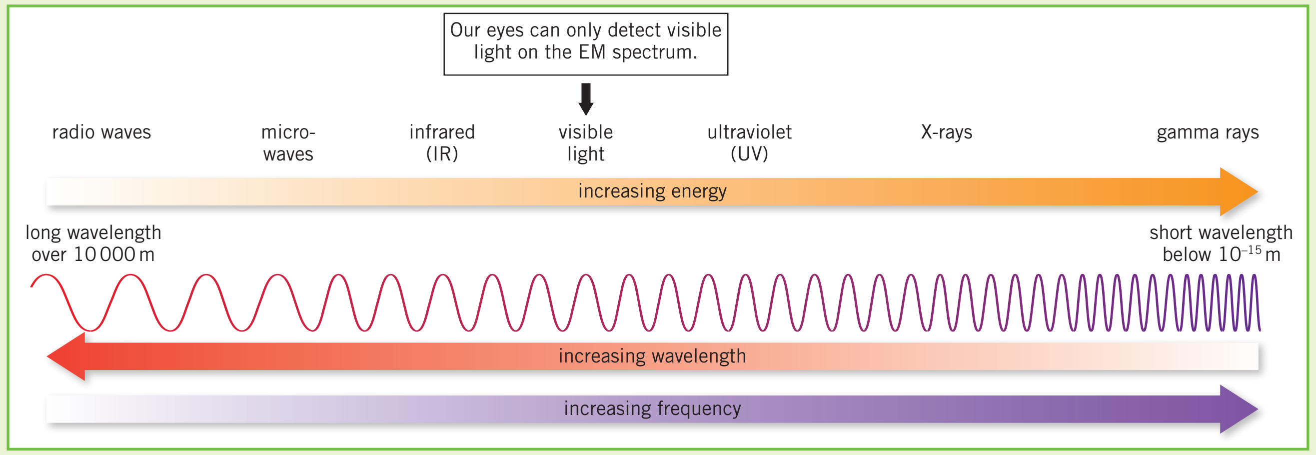
Electromagnetic (EM) waves are **transverse** waves that transfer energy from their source to an absorber. For example, infrared waves emitted from a hot object transfer thermal energy.

EM waves form a continuous **spectrum**, and are grouped by their wavelengths and frequencies.

EM waves all travel at the same velocity through air or a vacuum. They travel all at a speed of 3×10^8 m/s through a vacuum.

(HT only) Different substances may absorb, transmit, **refract**, or **reflect** EM waves in ways that vary with their wavelength.

Refraction occurs when there is a difference in the velocity of an EM wave in different substances.

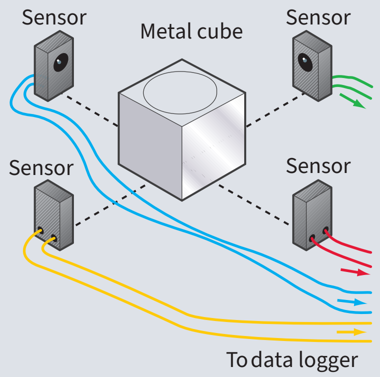


Infrared radiation (required practical)

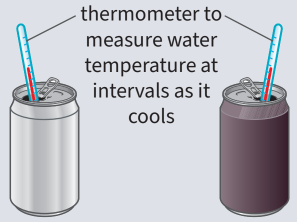
This practical investigates the rates of absorption and radiation of infrared radiation from different surfaces.

You should be able to plan a method to determine the rate of cooling due to emission of infrared radiation and evaluate your method.

Using infrared detectors to measure the radiation emitted by different surfaces



Monitoring the rate of cooling in cans with different surfaces



To be accurate and precise in your investigation you need to:

- use an infrared detector with a suitable meter, where possible
- ensure that you always put the detector the same distance from the surface
- repeat measurements and calculate an average.

Properties of EM waves

EM waves of a wide range of frequencies can be absorbed or produced by changes inside an atom or nucleus. For example, gamma rays are produced by changes in the nucleus of an atom.

When electrons in an atom move down between energy levels, they emit EM waves.

Properties of radio waves (HT only)

Radio waves can be produced by **oscillations** in an electrical circuit.

When radio waves are absorbed by a receiver aerial, they may create an **alternating current** with the same frequency as the radio waves.

Uses of EM waves

EM waves have many practical applications, but exposure to some EM waves (such as those that are forms of ionising radiation) can have hazardous effects.

Radiation dose (in sieverts) is the risk of harm from exposure of the body to a particular radiation.

Type of EM wave	Use	Why is it suitable for this use? (HT only)	Hazards
radio waves	television and radio signals	• can travel long distances through air • longer wavelengths can bend around obstructions to allow detection of signals when not in line of sight	can penetrate the body and cause internal heating
microwaves	satellite communications and cooking food	• can pass through Earth's atmosphere to reach satellites • can penetrate into food and are absorbed by water molecules in food, heating it	
infrared	electrical heaters, cooking food, and infrared cameras	• all hot objects emit infrared waves – sensors can detect these to turn them into an image • can transfer energy quickly to heat rooms and food	can damage or kill skin cells due to heating
visible light	fibre optic communications	• short wavelength means visible light carries more information	can damage the retina
ultraviolet (UV)	energy efficient lights and artificial sun tanning	• carries more energy than visible light • some chemicals used inside light bulbs can absorb UV and emit visible light	can damage skin cells, causing skin to age prematurely and increasing the risk of skin cancer, and can cause blindness
X-rays	medical imaging and treatments	• pass easily through flesh, but not denser materials like bone • high doses kill living cells, so can be used to kill cancer cells – gamma rays can also be used to kill harmful bacteria	form of ionising radiation – can damage or kill cells, cause mutation of genes, and lead to cancers
gamma rays			

Key terms

Make sure you can write a definition for these key terms.

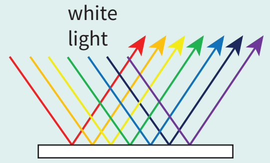
alternating current *electromagnetic wave* *electromagnetic spectrum*
oscillation *radiation dose* *reflection* *refraction* *transverse*

Chapter 14: Light

Knowledge organiser

Visible light

Each colour within the visible light spectrum has its own narrow band of wavelength and frequency.

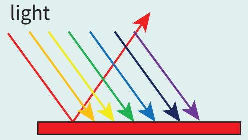


Reflection from:

- a smooth surface in a single direction is called **specular** reflection
- a rough surface causes *scattering* of light (**diffuse** reflection).

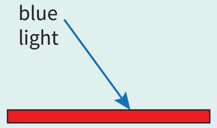
Transparent objects transmit visible light.

Translucent objects transmit visible light, but light rays are scattered or refracted inside them.



Opaque objects do not transmit visible light, but absorb and reflect it.

The colour of an object depends on the wavelengths they transmit and reflect.



Coloured filters work by absorbing certain wavelengths of light and transmitting others.

Magnification

Images formed by a lens can be:

- magnified of diminished
- upright or upside down (inverted).

The magnification of an image can be calculated using:

$$\text{magnification} = \frac{\text{image height}}{\text{object height}}$$

Magnification has no units because it is a ratio.

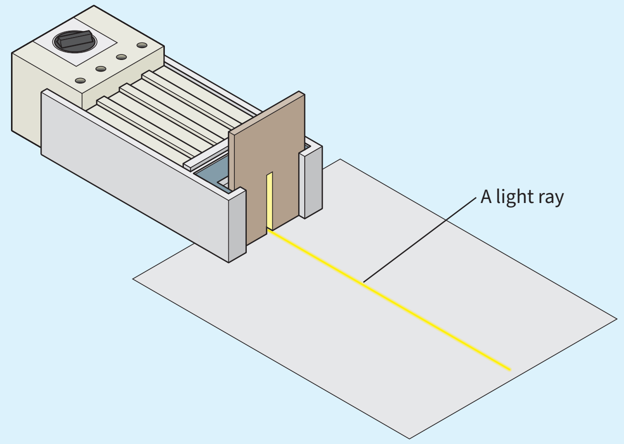
Reflection and refraction (required practical)

In this practical, you should have traced rays of light from a ray box as they interact with different surfaces or materials.

This includes investigating how light refracts as it passes through different materials, and how light is reflected by different surfaces.

To carry out accurate and precise investigations you need to:

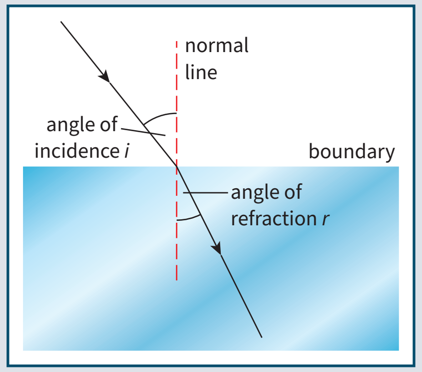
- use low light conditions
- place the slit in the ray box as far from the bulb as possible
- use a sharp pencil and ruler to draw the rays
- draw a line at 90° to any surface or boundary and measure all ngles from this line to the ray
- mark either side of solid block to work out the path of a ray nside the block.



Refraction of light

Ray diagrams show what happens when a wave is **refracted** (changes direction) at the boundary between two different substances.

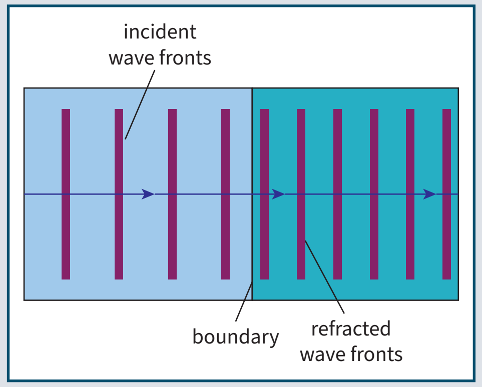
- If a wave slows down when it crosses the boundary, the refracted ray will bend towards the **normal**.
- If a wave speeds up when it crosses the boundary, the refracted ray will bend away from the normal.
- If a wave travels at a right angle to the boundary (along the normal), it will change speed but not direction.



Wave front diagrams can be used to explain refraction in terms of the change of speed that occurs when a wave travels from one substance to another.

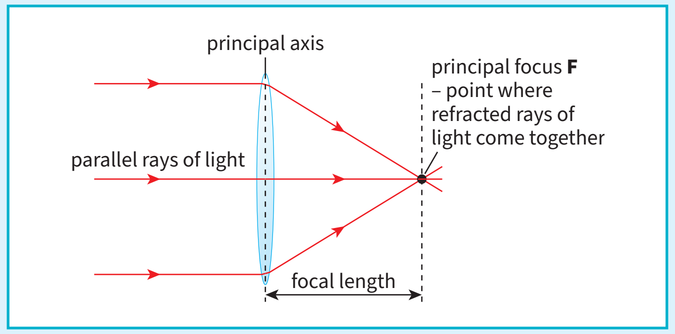
The wave front is an imaginary line at right angles to the direction the wave is moving.

- If a wave slows down as it crosses a boundary, the wave fronts become closer together.
- When a wave crosses a boundary at an angle, one end of the wave front changes speed before the other, so the wave changes direction.



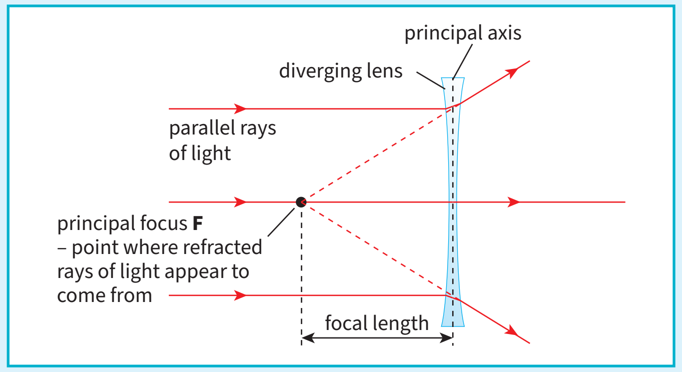
Convex lenses

Convex lenses curve outwards. They make parallel rays of light **converge** at a point. **Focal length** is the distance from the centre of the lens to the principal focus.



Concave lenses

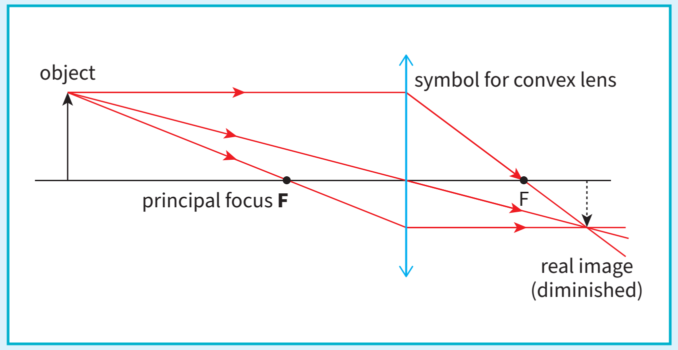
Concave lenses curve inwards. They make parallel rays of light **diverge** (so they appear to come from a point).



Forming images

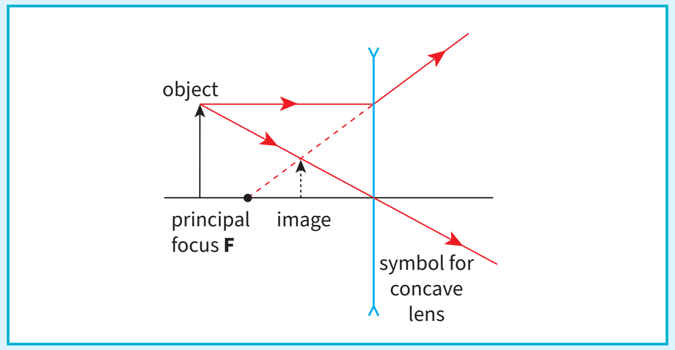
Images formed by **convex** lenses can be either real or virtual.

Real images can be projected onto a screen. **Virtual images** appear to come from behind the lens.



Forming images

Images formed by **concave** lenses are always virtual.



Key terms

Make sure you can write a definition for these key terms.

concave, converge, convex, diffuse, diverge, focal length
magnification, normal, opaque, ray diagram, real image, refract
specular, translucent, transparent, virtual image, wave front diagram

Chapter 15: Electromagnetism 1

Knowledge organiser

Magnets

Magnets have a north (N) and a south (S) pole.

When two magnets are brought close together, they exert a non-contact force on each other.

Repulsion – If the poles are the same (N and N or S and S), they will repel each other.

Attraction – If the poles are different (N and S or S and N), they will attract each other.

The force between a magnet and a magnetic material (iron, steel, cobalt, or nickel) is always attractive.

Magnetic fields

A **magnetic field** is the region around a magnet where another magnet or magnetic material will experience a force due to the magnet.

A magnetic field can be represented by magnetic field lines.

Field lines show the direction of the force that would act on a north pole at that point.

Field lines always point from the north pole of a magnet to its south pole.

A magnetic field's strength is greatest at the poles and decreases as distance from the magnet increases.

The closer together the field lines are, the stronger the field.

Induced and permanent magnets

A **permanent** magnet produces its own magnetic field which is always there.

An **induced** magnet is an object that becomes magnetic when it is placed in a magnetic field.

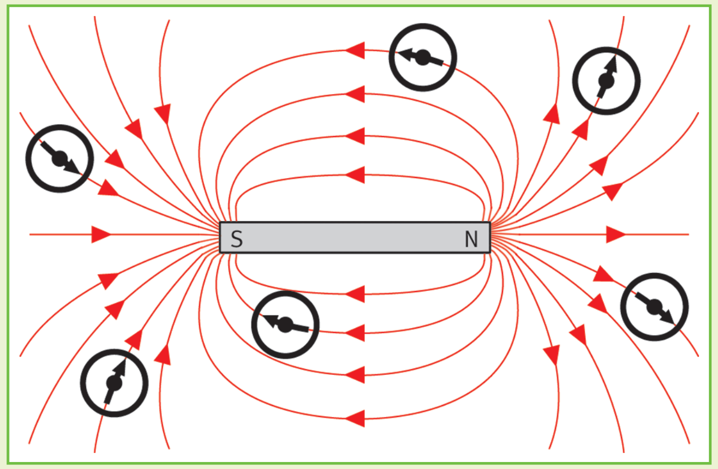
The force between an induced magnet and a permanent magnet is *always attractive* (it doesn't matter which pole of the permanent magnet the induced magnet is near).

If the induced magnet is removed from the magnetic field it will quickly lose most or all of its magnetism.

Plotting magnetic fields

A magnetic compass contains a small bar magnet that will line up with magnetic field lines pointing from north to south.

A compass can be used to plot the magnetic field around a magnet or an **electromagnet**:



If it is not near a magnet, a compass will line up with the Earth's magnetic field, providing evidence that the Earth's core is magnetic.

As a compass points towards a south pole, the magnetic pole near the Earth's geographic North Pole is actually a south pole.

Electromagnetism

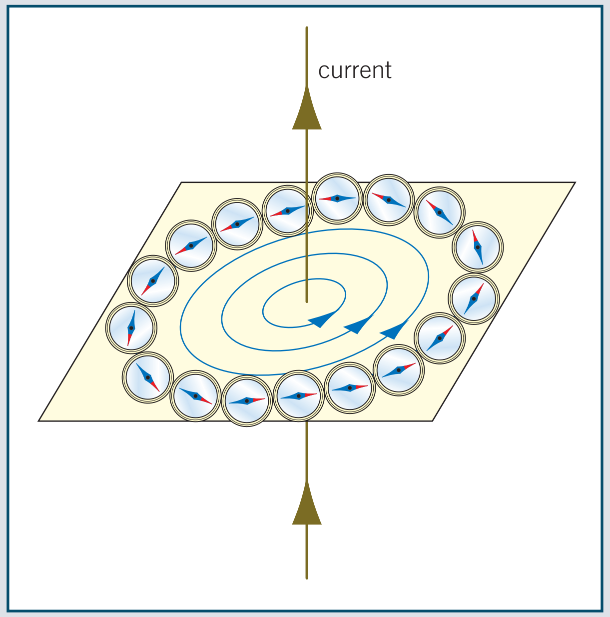
If an electric current flows through a wire (or other conductor), it will produce a magnetic field around the wire.

The field strength increases:

- with greater current
- closer to the wire.

Reversing the direction of the current reverses the direction of the field.

The field around a straight wire takes the shape of concentric circles at right angles to the wire:



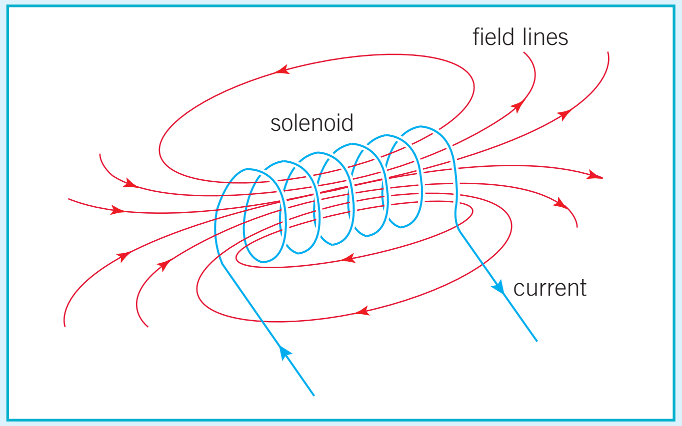
If the wire was gripped by someone's right hand so that the thumb pointed in the direction of the current, the fingers would curl in the direction of the magnetic field.

Solenoids

A **solenoid** is a cylindrical coil of wire.

Bending a current-carrying wire into a solenoid increases the strength of the magnetic field produced.

The shape of the magnetic field around a solenoid is similar to a magnetic field around a bar magnet.



Inside a solenoid the magnetic field is *strong* and *uniform*, which means it has the same strength and direction at all points.

The strength of the magnetic field around a solenoid can be increased by putting an iron core inside it.

If the wire was gripped by someone's right hand so that the fingers curl in the direction of the current in the coil, the thumb will point towards the north pole of the field.

Electromagnets are often solenoids with an iron core.

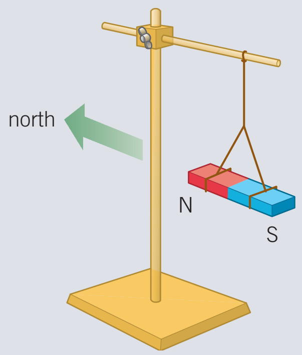
Advantages of electromagnets

- An electromagnet can be turned on and off.
- The strength of an electromagnet can be increased or decreased by adjusting the current.

Magnetic materials

Iron or steel objects, and some nickel and cobalt materials can be magnetised or demagnetised. Magnets made of steel tend to be more permanent as it does not lose its magnetism easily.

N-pole and S-pole can be identified by suspending a bar magnet, and using a second magnet to identify each pole.



Chapter 15: Electromagnetism 2

Knowledge organiser

Uses of electromagnets

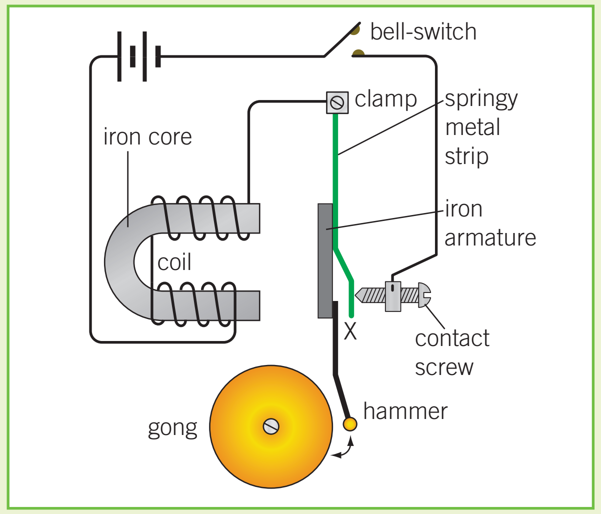
Scrap-yard crane

Heavy objects containing magnetic materials can be lifted using an electromagnet.

Electric bell

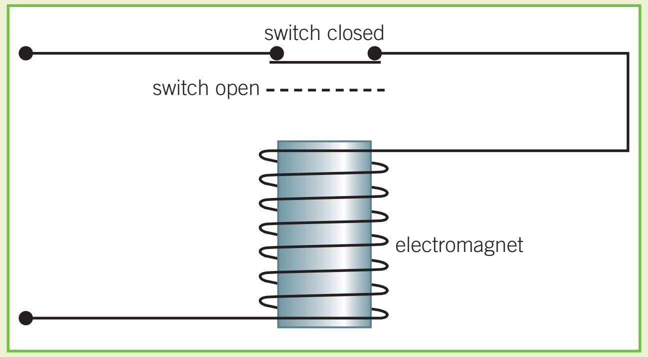
The diagram below shows how an electric bell operates.

- switch is pressed, turning the electromagnet on
- the iron armature is attracted towards the electromagnet, making the hammer strike the gong
- the circuit is broken so the electromagnet stops working and the armature springs back
- circuit is complete again and the cycle starts again, continuing as long as the switch is pressed.



Circuit breaker

A switch that is in series with an electromagnet.



The switch is held closed by a spring, but if the current becomes too large, the electromagnet becomes strong enough to pull the switch into the open position, turning the current off.

The motor effect (HT only)

When a current-carrying wire (or other conductor) is placed in a magnetic field, it experiences a force.

The force is due to the interaction between the field created by the current in the wire and the magnetic field in which the wire is placed.

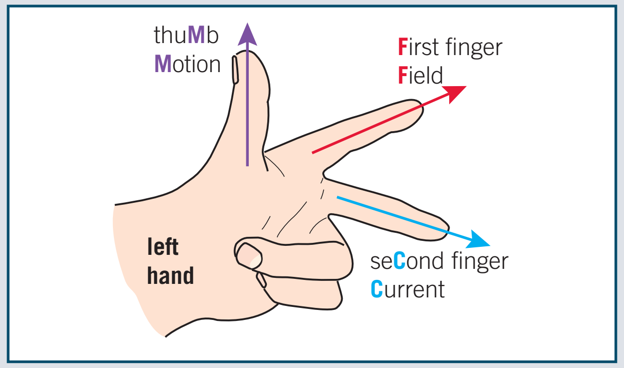
The magnet producing the field will experience an equal-sized force in the opposite direction.

The direction of the force is reversed if the current is reversed or if the direction of the magnetic field is reversed.

Fleming's left-hand rule (HT only)

The direction of the force/motion of the wire is always at right angles to both the current and the direction of the magnetic field it is within.

It can be worked out using Fleming's left-hand rule:



Magnetic flux density (HT only)

The **magnetic flux density** of a field is a measure of the strength of the magnetic field.

For a current-carrying wire at right angles to a magnetic field, the size of the force on it is given by the equation:

force (N) = magnetic flux density (T) × current (A) × length (m)

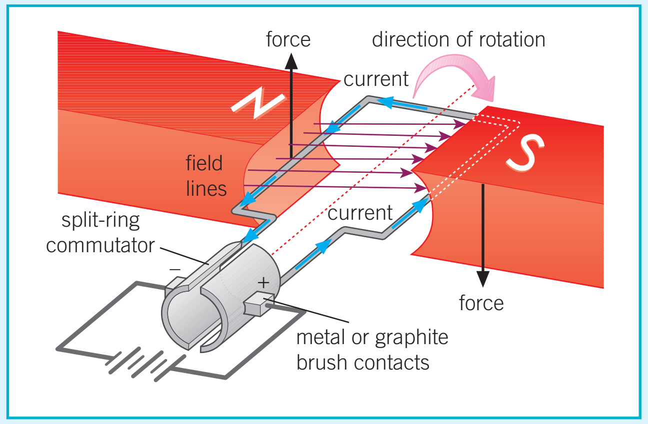
$$F = BIl$$

Electric motors (HT only)

A current-carrying coil of wire in a magnetic field will tend to rotate.

This is the basis of an electric motor.

The diagram below shows a simple motor made of one rectangular piece of wire.



When there is a current in the wire, it spins because:

- each side of the coil experiences a force due to being a current-carrying conductor in a magnetic field
- the forces on each side of the coil are in opposite directions.

The **split-ring commutator** keeps the motor spinning in the same direction.

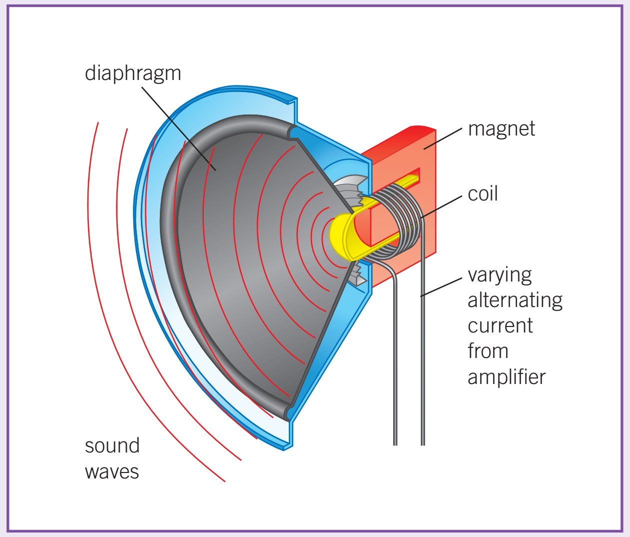
The ends of the wire swap contacts with the power supply every half turn, so current always flows in the same direction relative to the magnetic field.

The motor can be made to spin

- *faster* – by increasing the current in the coil or increasing the strength of the magnetic field.
- *in the opposite direction* – by reversing the direction of the current or reversing the direction of the magnetic field.

Loudspeakers

Moving-coil loudspeakers and headphones use the **motor effect** to convert changes of current in a coil of wire to changes of pressure in sound waves.



A coil of wire is placed inside a permanent magnet (so it is inside a magnetic field) and is attached to a diaphragm.

When a current flows through the coil, it experiences a force due to the motor effect.

This causes the diaphragm to move.

When the current changes direction, the force on the coil also changes direction, causing the diaphragm to move in the opposite direction.

Variations in the current make the coil and diaphragm vibrate.

These vibrations create variations of pressure in the air which form a sound wave.

The frequency of the sound wave produced is the same as the frequency of the alternating current supplied to the coil.

Key terms

Make sure you can write a definition for these key terms.

attraction, electromagnet, induced, magnetic field, magnetic flux density, motor effect, split-ring commutator, permanent, repulsion, solenoid

Chapter 16: Space

Knowledge organiser

Our Solar System

Our **Solar System** is made up of the Sun (a star) and all the objects that orbit it, including:

- eight planets
- asteroids
- dwarf planets
- comets
- moons (natural **satellites**) that orbit planets

The Sun is located in the **Milky Way galaxy**, which contains billions of other stars.

Formation of stars

The Sun (and all other stars) was formed from a huge cloud of dust and gas (a **nebula**) pulled together by **gravitational attraction**.

Gravitational attraction between the particles of dust and gas causes them to merge together to form a **protostar**.

The protostar becomes denser as gravitational forces continue to pull it together, so the particles in the protostar collide more often.

More energy from the gravitational potential energy store of the particles is transferred to the thermal energy store, so the temperature of the protostar increases.

When the temperature is high enough, hydrogen nuclei fuse together to form helium nuclei.

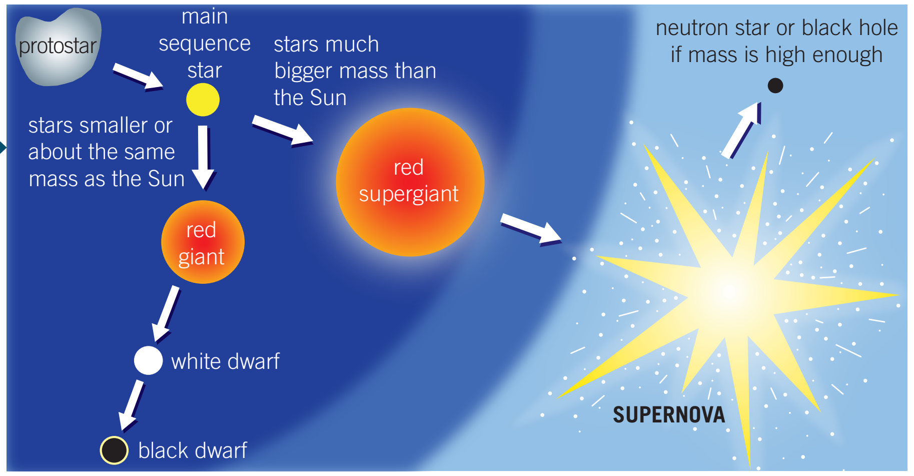
These nuclear fusion reactions release huge amounts of energy and the protostar becomes a **main sequence star**.

This star is stable because the fusion reactions produce outwards forces which are in equilibrium with the gravitational forces pulling it inwards.

Life cycles of stars

All stars go through changes as part of a life cycle. The life cycle of a particular star is determined by its mass.

Starting as a nebula, stars with the same mass as the Sun, and more massive than the Sun, follow specific life cycles.



Formation of the elements

The nuclei for all the naturally occurring elements are produced by nuclear fusion in stars:

- hydrogen nuclei are fused together to form helium nuclei
- other small nuclei are formed in stars with large masses
- when a star becomes a red giant or red supergiant, helium, lithium, and other small nuclei are fused to form larger nuclei.

Elements heavier than iron require more energy to be produced, so are only produced when a massive star explodes (a **supernova**).

The elements produced in stars are distributed throughout the universe by massive stars going supernova.

Orbital motion and satellites

The Earth and other planets in the solar system **orbit** the Sun.

The Moon is a natural satellite that orbits the Earth, while other planets have other moons orbiting them.

The Earth also has artificial satellites orbiting it.

When one object orbits another, the less massive (smaller) object orbits the more massive (bigger) one.

Circular orbits (HT only)

The Moon and the artificial satellites around the Earth move in circular orbits, while the orbits of the planets around the Sun are almost circular.

At any instant in time, the direction of the velocity of an object in a circular orbit is at right angles (perpendicular) to the direction of the resultant force acting on it.

Since the resultant force is at right angles to the velocity, it does not cause the object to speed up but only changes its direction.

An object moving in a circle is constantly changing direction, meaning it is constantly changing velocity (though not speed).

The object must therefore also be constantly accelerating, and so have a resultant force acting on it.

This resultant force is called the **centripetal force** and is always directed towards the centre of the circular orbit, so the acceleration of the object is always directed towards the centre.

For planets and satellites, gravity provides the resultant force that maintains their circular orbits.

Stable orbits (HT only)

To stay in a stable orbit at a fixed distance from a larger object, the smaller object must move at a particular speed.

If the speed of an object in a stable orbit changes, the radius of the orbit must also change.

The slower the speed of an orbiting object, the bigger the radius of the circle it moves in.

Red-shift

Red-shift is the name given to the effect that makes the wavelengths of light *longer* if the light source is moving away from the observer.

Scientists have observed that the wavelengths of light from most distant galaxies are longer than expected – they are red-shifted.

This suggests that these galaxies are moving away from the Earth.

The further away galaxies are, the more their light is red-shifted, suggesting distant galaxies are moving away from Earth faster than close galaxies.

These observations suggest that the universe (space itself) is expanding.

Since 1998, scientists have observed light from supernovae that suggests distant galaxies are moving away faster and faster.

This indicates that the speed at which the universe is expanding is increasing.

Big Bang theory

Scientists used these observations to propose the **Big Bang theory** for the start of the universe.

The Big Bang theory suggests that the universe started off as an extremely small, hot, and dense object that exploded.

As well as the red-shift of light from galaxies, there is other evidence to support the Big Bang theory, like the existence of electromagnetic radiation that was produced just after the Big Bang.

Scientists still do not know or understand much about the universe or how it began.

For example, they think **dark energy** could be responsible for the acceleration of the expansion of the universe, and **dark matter** might provide the gravitational force holding galaxies together.

But these things are not understood, and models like the Big Bang theory may change following new observations.

Key terms

Make sure you can write a definition for these key terms.

Big Bang theory, centripetal force, dark energy, dark matter, gravitational attraction, main sequence star, Milky Way galaxy, nebula, orbit, protostar, red-shift, satellite, solar system, supernova